

# Order Entry Protocols Are an Amenable Target for Workflow Automation

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## Abstract

**Purpose:** Order entry protocol selection of advanced imaging studies is labor-intensive, can disrupt workflow, and may displace staff from more valuable tasks. The aim of this study was to explore and compare the behaviors of radiologic technologists and radiologists when determining protocol to identify opportunities for workflow automation.

**Methods:** A data set of over 273,000 cross-sectional examination orders from four hospitals within our health system was created. From this data set, we isolated the 12 most frequently requested examinations, which represent almost 50% of the entirety of advanced imaging volume. Intergroup comparisons were made between behavior of radiologic technologists and radiologists or residents when determining protocol. Frequencies of changes were calculated. Common parameters of changed examinations were identified.

**Results:** The overall change rate for both radiologists and residents (4%) is very low and comparable to the overall change rate of radiologic technologists (1%). The change rates for the 12 most ordered examinations were calculated and compared individually. Most examinations that underwent change involved a patient with a low estimated glomerular filtration rate, a patient with a contrast allergy, or a provider ordering a general examination but in fact wanting an organ-specific protocol or an angiographic study.

**Conclusion:** Order entry protocol selection of the most frequently ordered advanced imaging examinations was rarely a value-added activity because these examinations are rarely changed. Changes follow predictable patterns that make order entry protocol selection of most radiology orders for advanced imaging amenable to workflow automation.

**Key Words:** Workflow automation, determining protocol, data analysis, workflow, value-added activity

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## INTRODUCTION

Radiology information systems generate large amounts of data at every step of the workflow, from initial order entry to image acquisition and radiologist reporting. Our institution performs approximately 1.5 million studies per year. Approximately 250,000 of these are advanced imaging studies (CT, MRI, and nuclear medicine). Protocol selection for these studies is an important part of the workflow where the requested study is reviewed, both for appropriateness of the examination and to confirm its technical parameters [1]. This process of protocol selection of advanced imaging studies is labor-intensive, can disrupt workflow, and may displace staff from more

valuable tasks [2]. Our health system has been electronically selecting protocols of advanced studies since 2008. Since that time, our department has collected information regarding ordered studies and how the protocol was determined before completion. We sought to examine patterns in our cross-sectional order entry protocol selection by examining two specific case scenarios. At two of our primary hospitals, protocol selection of advanced studies is performed by radiologists or radiology residents. However, at two of our satellite hospitals, protocol selection is handled by the radiologic technologists. Using data from our internally developed order entry protocol system, we sought to understand the similarities and differences in the two protocol groups to possibly improve the practice systemwide by asking three specific questions: how often examinations are changed, whether the modified examinations have certain characteristics, and whether this step would be amenable to automation based on characteristics of these examinations.

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## METHODS

Our institution's radiology information system and internally developed order entry protocol selection application were used to generate a data set of 273,313 cross-sectional (CT or MRI) examination orders created between April 22, 2015, and November 9, 2016, across the four hospitals investigated. Not all orders were completed for various reasons that could not be determined from the available data. Those studies were excluded from analysis. Fields for requested examination code, selected examination code, International Classification of Diseases diagnosis code, free text history, date, and contrast change were included for all locations. Examination ID and parent ID number were included when available.

Data analysis was performed with the Python programming language (Python Software Foundation, Wilmington, Delaware) paired with the data analysis module Pandas [3].

Duplicates were removed. We calculated how often the 12 most commonly requested examinations were changed to another examination code by both the radiologic technologist group and by the radiologist and resident group. If a requested examination at the two primary hospitals was changed to another examination more than 5% of the time, an adjusted change rate was calculated by excluding changes that reflected only consolidations of multiple examinations or organ-specific examinations specifically requested by the ordering clinician.

Our primary campus maintains an image quality control reporting system for radiologists to electronically flag problems with individual studies. We evaluated all the reports filed in these databases during the study period, which totaled 1,283 studies. Two hundred fifty of these image quality control reports flagged 1 of the 12 most commonly requested examinations. Standardized categories of these reports include, among others: incorrect positioning, artifacts, poor reconstructions, missing images, incorrect order, and incorrect protocol. The satellite hospitals do not maintain an electronic image quality reporting system.

All data sets were then compared to help further understand the patterns of protocol selection of the two groups—technologists and radiologists.

## RESULTS

Over an approximately 19-month period between April 22, 2015, and November 9, 2016, 128,222 examinations were ordered at the primary hospitals, and 146,091 examinations were ordered at the satellite hospitals. [Table 1](#) shows how often the 12 most requested examinations

were changed by radiologic technologists at the two satellite hospitals. [Table 2](#) shows how often the 12 most requested examinations were changed by radiologists and residents at the two primary hospitals.

If an examination was changed more than 5% of the time, an adjusted total was calculated to exclude examinations that were part of multiple orders that were consolidated into one examination. Also, examination requests with clinician comments that specified an organ-specific or angiographic examination were also excluded. [Table 3](#) shows the selected examinations for the changes made to a CT of the chest, abdomen, and pelvis with contrast, with the adjusted change.

[Table 4](#) demonstrates which examination codes were selected by radiologists and residents when CT chest with contrast were changed. It also shows the adjusted total.

Similar adjustments were made to MRI brain with or without contrast, CT chest without contrast, and CT of the chest, abdomen, and pelvis with contrast. [Table 5](#) shows how often examinations are changed by the two groups with the adjusted change rate.

We reviewed 100% of the image quality control reports filed at the primary hospitals during our study period. Of those, 250 flagged studies involved the 12 most ordered examinations, but none of these studies were flagged due to incorrect protocol. Of the 1,033

**Table 1.** Protocol of the 12 most ordered examinations within our health system as determined by radiologic technologists at two of the satellite hospitals within our institution

Examination Code	# Requests	# Changes	% Changed
CTHDWO	28,039	8	<1
CTEABDW	4,483	48	1
MRBRAW-WO	3,940	68	2
MRBRA	3,255	29	1
MRLSP	4,897	18	<1
MRCSP	2,626	2	<1
MRAHEAWO	658	0	0
CTCHW	3,925	184	5
CTCHWO	4,486	150	3
CTEABDWO	4,483	48	1
CTRENALSTO	4,746	1	<1
CTPECHESTW	5,450	1	<1
Total	70,988	557	1

CTCHW = CT chest with contrast; CTCHWO = CT chest without contrast; CTEABDW = CT abdomen and pelvis with contrast; CTEABDWO = CT abdomen and pelvis without contrast; CTHDWO = CT head without contrast; CTPECHESTW = CT pulmonary embolism protocol; CTRENALSTO = CT renal stone protocol; MRAHEAWO = MR angiography head without contrast; MRBRA = MRI brain without contrast; MRBRAW-WO = MRI brain with or without contrast; MRCSP = MRI cervical spine; MRLSP = MRI lumbar spine.

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